The effect of height of maximum density (hm) changes on the ordinary wave critical frequency of the f2 layer (fof2) in the quiet equatorial ionosphere

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THE EFFECT OF HEIGHT OF MAXIMUM DENSITY (h_m) CHANGES ON THE ORDINARY WAVE CRITICAL FREQUENCY OF THE F_2 LAYER (f_0F_2) IN THE QUIET EQUATORIAL IONOSPHERE.

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Abstract
This paper discusses the effect of h_m changes on f_0F_2 . A set of theoretical $h'f$ (minimum vertical height on the ordinary- wave branch for the F layers) curves called overlays were constructed from a parabolic equation. Δf_0F_2 , h_m and Δh_m parameters were calculated for June Solstice (representing May to August) and September Equinox (representing September and October) at 0900 hours, 12 00 hours and 1500 hours. The results obtained show that as Δh_m increases, Δf_oF_2 increases, indicating that height changes in the F_2 layer shows a corresponding change in the critical frequency of the layer. The correction for Δh_m, show a shift in f_oF_2 for the Solstice and Equinox.

Key Words: Equinox, f_0F_2 , Ionosphere, Equatorial, Solstice

Introduction

The Ionosphere is greatly affected by solar disturbance such as appearance of sunspots, solar flares and corpuscular streams which are accompanied by an increase in velocity and concentration of the solar wind thus ejecting more energetic ions which are observed on the earthǿs surface as geomagnetic storms. The disturbance effect in the F_2 layer is remarkable during a geomagnetic storm.

Several studies have been made on the relationship between the height of maximum electron density h_m and f_oF_2 (ordinary-wave critical frequency in the F2 region) during magnetic storm situations. In this study, the relationship between Δh_m and Δf_oF_2 was carried out for quiet days in the equatorial lonosphere.

The selection of quiet days for this study was based on data readily available and the Ap indices (geomagnetic amplitudes) which are more influenced by short term transient variations. Thus a satisfactory estimate Ap less than or equal to 10 (Ap Ò 10) was taken as indicating a magnetically quiet day (arbitrary) and the result therefore describe the behavior of the undisturbed F_2 region.

Analysis

Generally, the determination of the height of maximum density (h_m) of a layer is subject to two main difficulties which are: the convergence of solutions of the integral equations is very poor near a critical frequency, f_o, and the systematic experimental errors due to small errors

in frequency determination when the virtual height varies rapidly with frequency.
In this study, a set of theoretical h′f (minimum Virtual height on the ordinary – wave branch for the F layer) curve called overlays were constructed by using equation of a parabola

$$h'^2 = 4a\,(f_o - f)$$

where "a" is in constant.

This method gave extra information on the curvature of the ionization profile near its peak. The assumption was that Variation of ionization density with height near the peak must be parabolic. The curvature of the profile near maximum is the parameter which mainly determines the total amount of ionization below the Centre of the layer which in effect gives the thickness of the densest part of the layer.
The theory of the method is derived from the equation

$$N = N_m\left[1 - \left(\frac{h - h_m}{2qc}\right)^2\right]$$

Where Nm, hm and qe are the maximum Value of electron density N, the height of maximum density and the quarter thickness of the parabola respectively. The plasma frequency f_N is given by:

$$f_N^2 = f_{Nm} = N_m\left[1 - \left(\frac{h - h_m}{2qc}\right)^2\right]$$

where F_{Nm} is the critical frequency of the layer for the ordinary ray.

But

$$h_m = h + 2qc\sqrt{1 - \frac{f_N^2}{f_0^2}}$$

Where h = 0.95f_o
i.e. hm = h + dqc ----- --------------- (1)

Where $d = 2X\sqrt{1 - \frac{f_N^2}{f_0^2}}$ -------------------(2)

Thus, a set of theoretical h′f curve called overlays were constructed by using equation of a parabola.

$$h'^2 = 4a\,(fo - f)$$

where "a" is a constant.

These overlays which must correspond to the band f_o fall are then matched on the observed trace of the Ionogram, such that it agrees with overlays in the range of $0.95f_o$ and f_o approximately. This was done by moving it horizontally and vertically, until one trace fits

the ordinary Ionogram trace. Also the height of the Ionogram must correspond to that of the overlay; if not a multiplying factor is given to the overlays. Thus, h_m and qc are calculated to a high accuracy. From (1) and (2) above, if a true height h is calculated for plasma frequency f such that $f = 0.95f_o$ as earlier stated, then d will be 0.625 and

$$h_m = h\, 0.95\, f_o + 0.625\, qc$$

Where $h = 0.95f_o$ = true height.

Data Collection

The data used for this study were collected from the readings of an ionosonde which were recorded into booklets. The Ionosonde is the Ionospheric Sounder used at Ibadan. The period covered by data is January to December 1958; (a year of sunspot maximum)

Ibadan has geographic coordinates

$07^o\ 24^/$ N, $03^o\ 54^/$ E,

geomagnetic coordinates + 10.6^o, 74.6^o

Magnetic dip ï 6^0 and Time meridian 0^o

Equipment Details

Frequency range 0.67 Mc/s ï 25 Mc/s in fine band

Band 1 0.67 ï 1.4Mc/s 0-1 Minute after start

Band 2 1.4 ï 3.1 Mc/s 1 ï 2 minutes after start

Band 3 3.1 - 6.9 Mc/s 2- 3 minutes after start

Band 4 6.9 - 15.4 Mc/s 3 ï 4 minutes after start

Band 5 15.4 - 25 Mc/s 4 - 5 minutes after start

Sweep time = 5 minutes.

Peak Power : 1KW approx.

Pulse repetition rate: 50 p.p.s

Pulse length : 80 µs to 330 µs, normally 100µs

Aerial in use: Vertical rhombic

Readings, normally every hour, are made on 70 mm photographic paper and the time reference is that when the sounder sweep starts.

Results and Discussion

Following the division of the year into seasons by Danilov et al (2001), the different seasons are September and October representing September Equinox, May to August representing June solstice.

Tables I and 2 below shows the parameters obtained from the analysis so far discussed for the June Solstice and September Equinox at the hours indicated.

TABLE 1
JUNE SOLSTICE

0900 Hrs.	h (km)	h_m (km) = h+0.625 qc	△ f_oF_2(mHz)	△ h_m=h-h_m	Qc
	415	500	2.3	79	120
	395	480	2.0	59	
	365	450	1.1	29	
	345	430	0.4	9	
	343	428	0.1	7	
	332	417	0.3	4	
	297	382	1.4	39	
	280	365	1.6	56	
	255	340	2.6	81	
12.00 hrs.	573	673	2.9	150	qc = 160
	538	638	2.6	105	
	507	607	1.6	84	
	450	550	0.6	27	
	396	496	0.4	27	
	370	470	2.2	53	
	302	402	3.4	188	
1500 hrs.	247	347	3.0	168	qc = 480
	501	801	1.2	82	
	437	737	0.8	18	
	376	676	0.4	43	
	339	639	1.6	80	
	277	577	2.4	142	

TABLE 2

SEPTEMBER EQUINOX

0900 Hrs.	**h (km)**	**h_m (km) = h+0.625 qc**	**△ f_oF_2(mHz)**	**△ h_m=h- h_m**	**Qc**
	419	504	2.2	89	qc =120
	381	466	0.8	51	
	378	463	0.6	32	
	355	440	0.4	25	
	327	412	0.3	3	
	310	395	0.1	20	
	285	370	1.2	45	
	264	379	1.6	66	
	247	332	2.0	83	
1200 hrs.	514	554	3.0	153	qc=320
	471	511	1.4	69	
	389	429	1.2	13	
	340	380	0.8	62	
	309	349	2.0	93	
	269	309	2.8	133	
	247	287	3.2	155	
1500hrs	569	669	2.8	140	qc=160
	515	615	1.4	86	
	484	584	0.6	55	
	465	557	0.2	28	
	456	556	0.4	27	
	412	512	0.1	17	
	365	465	1.0	64	
	330	430	1.8	99	
	276	376	2.6	130	

TABLE 3

JUNE SOLSTICE

Time	00	03	06	10	12	13	16	19	20
Δ	1.7	1.1	0.5	0.7	1.4	0.9	0.4	0.8	0.6
δ_m	0.6	0.4	0.2	0.2	0.5	0.3	0.1	0.3	0.2

TABLE 4
SEPTEMBER EQUINOX

δ	1.4	1.1	0.4	1.1	0.8	0.8	0.8	0.9	1.4
δ_m	0.6	0.4	0.1	0.4	0.2	0.3	0.2	0.3	0.5

From the graphs drawn using the above tables (figs. 1-6) it is clear that as h_m $\triangle$increases, $\triangle f_oF_2$ also increases showing that height changes in the F_2 layer show a corresponding change in the ordinary-wave critical frequency of the layer.

The correction for Δh_m shows a shift in Δf_oF_2 as seen in figs 7 and 8 for the solstice and Equinox. Table 3 shows the error estimation values obtained against some chosen hours of the day. The physical significance in this case, is that the changes which occur in going from day to night conditions depend on the degree of magnetic activity present and the layer height.

Conclusion

The result obtained from this study shows a linear relationship between h_m and f_oF_2. This indeed does not particularly give any serious information about the re-distribution of Ionospheric ionization. It is therefore suggested that to determine changes in the electron content of the ionosphere during storms, the use of N-h profile may be considered. The data established by this study are proposed as equatorial input values for the development of a viable model for the international reference ionosphere, to map out and characterize the structure of the Ionospheric plasma.

References

Budden, K.C. (1966). Radio waves in the Ionosphere, Cambridge University.

Danilov, A.D and Mikhailov A.V (2001). ñLong term trends in F2 layer parameters at Argentine Island and Port Stanley Stationsò, *Annals' of Geophysics*, 41(4) 488-496

King, G. A. M (1957). ñRelation between Virtual and actual heights in the Ionosphereò, J. Amos. *Terr. Phy*; II, 209-20.

Maruyama, T, et al (1996). ñModeling study of Equatorial Ionospheric height and spread F occurance. *J Geophys.Res*, 101,5157-5163.

Massey H.S.W. and Boyd. R.I.F. (1961). *The Upper atmosphere*, Hutchinsen and Co. Publishers Ltd.

Rishbeth, H. (1962.). ñAtmospheric Composition and the F layer of the Ionesphereò, *Planet Space Sci.* 9, 149-158.

Ractliffe, J. A. (1951). ñSome Regularities in the F_2 Region Ionosphere, *J. Geophys. Res*; 56, no. 4, 487-507

Ractliffe, J. A. (1956). ñA Quick Method for Analyzing Ionospheric Recordsò, *J. Geophys. Res*. 56, 463 ï 485.

Yokoyama, T, et al (2004). ñRelationship of the on Set of the Equatorial F Region Irregularities with the Sun-Set Terminator observed with the Equatorial Atmosphereò, *Radar Geophys. Res.* Lett 31, L24804,doi,10,1029/2004 GL021529,2004.

Appendix

```
ListPlot[{{2.3,79.0},{2.0,59.0},{1.1,29.0},{0.4,9.0},{0.1,7.0},{
1.3,4.0},{1.4,39.0},{1.6,56.0},{2.6,81.0}}]
```

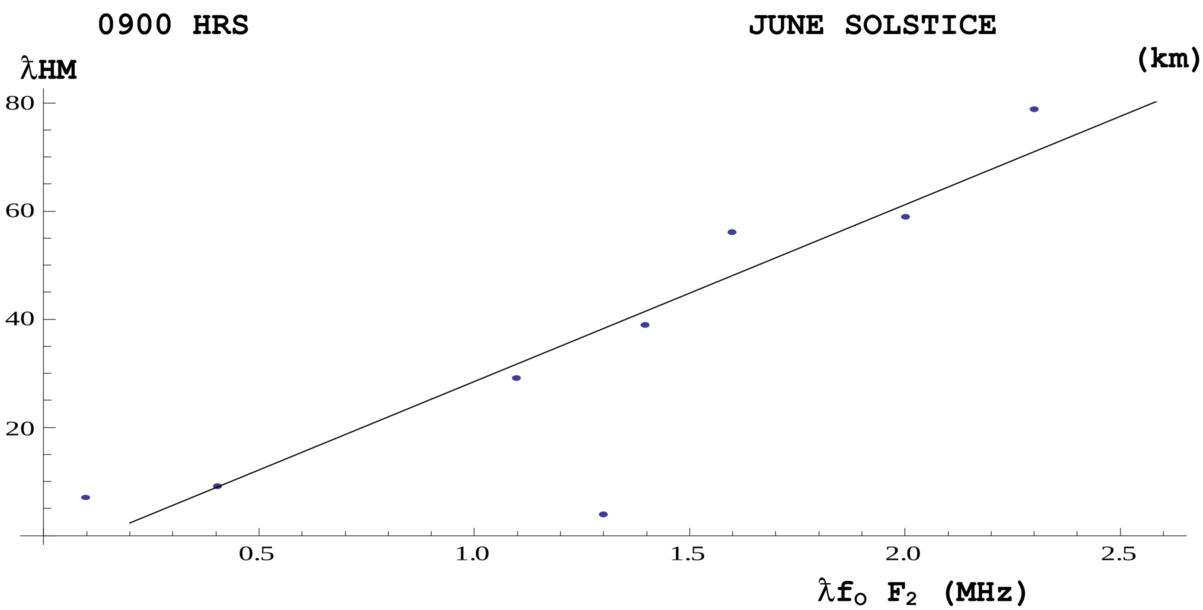
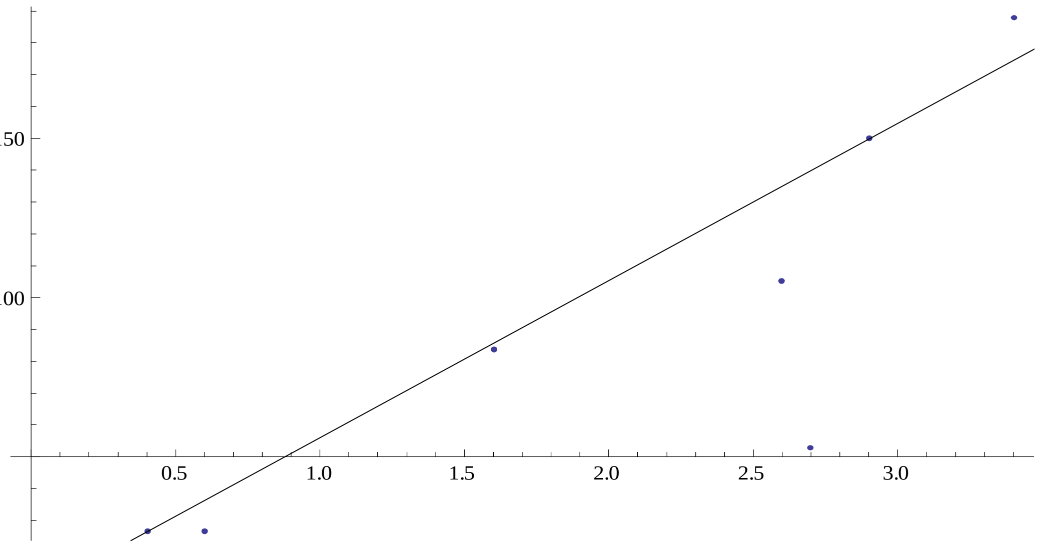


Fig 1

```
ListPlot[{{2.9,150.0},{2.6,105.0},{1.6,84.0},{0.6,27.0},{0.4,27.
0},{2.7,53.0},{3.4,188.0}}]
```

1200 HRS **JUNE SOLSTICE**

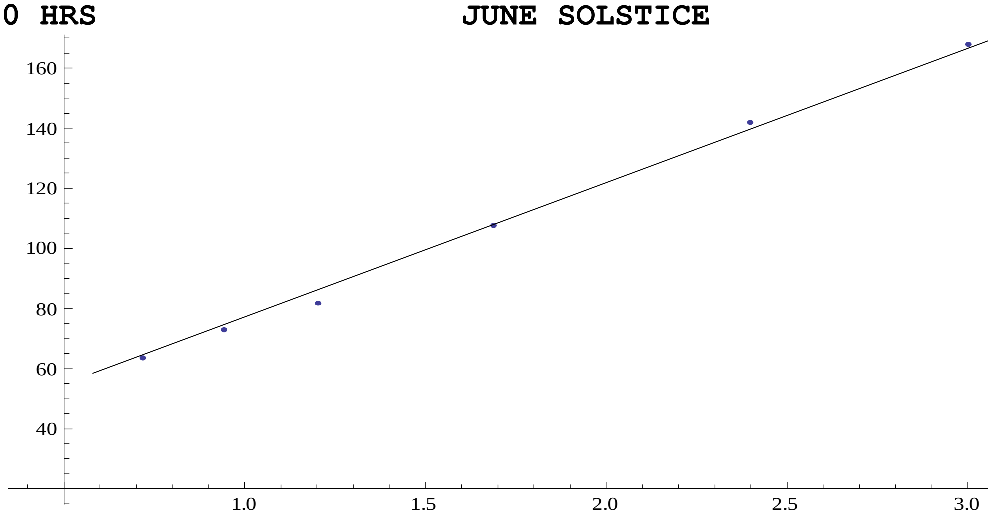


λHM (km)

Fig 2 **λf_o F_2 (MHz)**

```
ListPlot[{{3.0,168.0},{1.2,82.0},{0.8,18.0},{0.4,43.0},{1.6,30.0
},{2.4,142.0}}]
```

1500 HRS **JUNE SOLSTICE**



λHM (km)

Fig 3 **λf_o F_2 (MHz)**

```
ListPlot[{{2.2,89.0},{0.8,51.0},{0.6,32.0},{0.4,25.0},{0.3,3.0},
{0.1,20.0},{1.2,45.0},{1.6,66.0},{2.0,83.0}}]
```

0900 HRS **SEPTEMBER EQUINOX**

λHM **(km)**

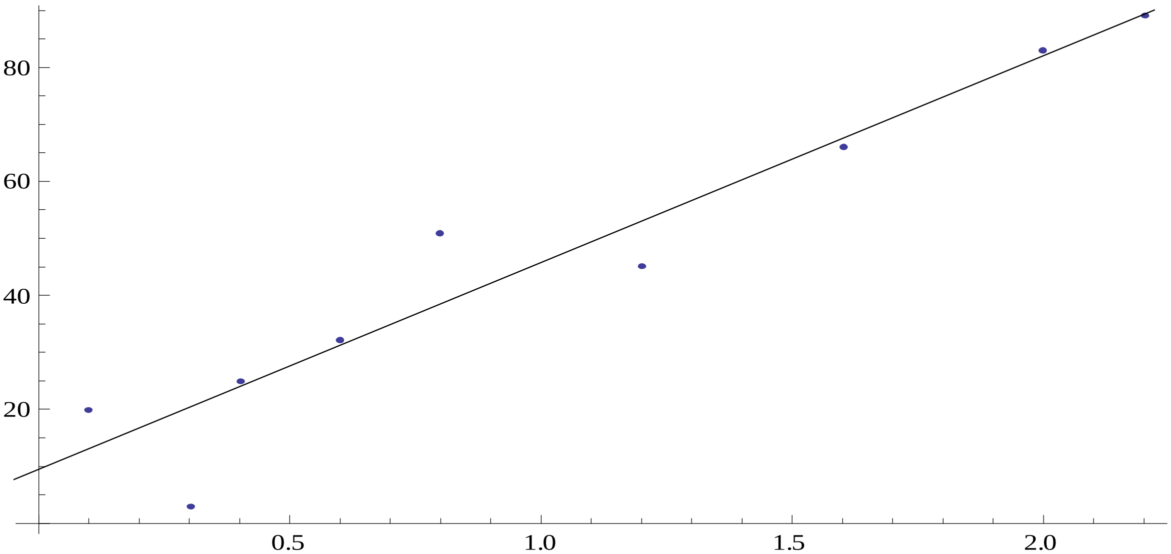


Fig 4

λf_o F_2 (MHz)

```
ListPlot[{{3.0,153.0},{1.4,69.0},{1.2,13.0},{0.8,62.0},{2.0,43.0
},{2.8,133.0},{3.2,155.0}}]
```

1200

SEPTEMBER EQUINOX **HRS**

λHM **(km)**

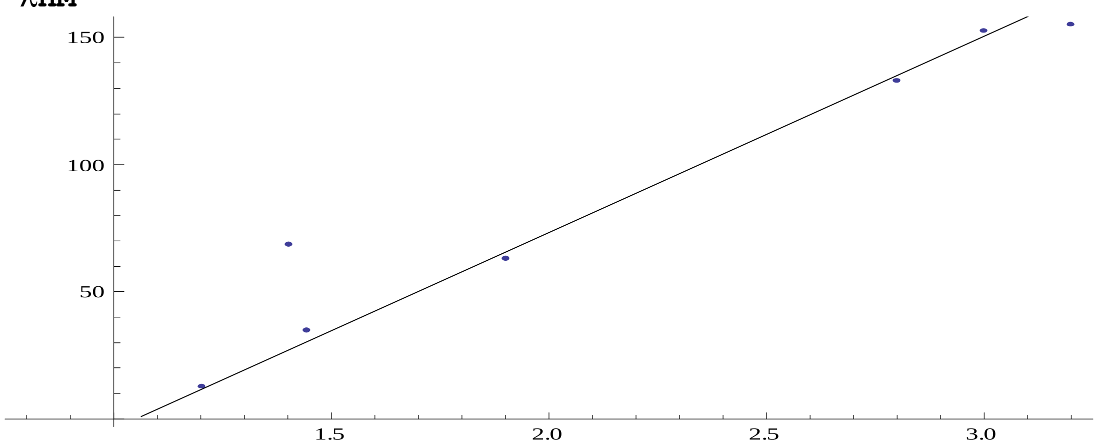


Fig 5 **λf_o F_2**

(MHz)

**ListPlot[{{2.8,140.0},{1.4,86.0},{0.6,55.0},{0.2,28.0},{0.4,27.0},
{0.1,17.0},{1.0,64.0},{1.8,99.0},{2.6,130.0}}]**

1500 HRS
SEPTEMBER EQUINOX

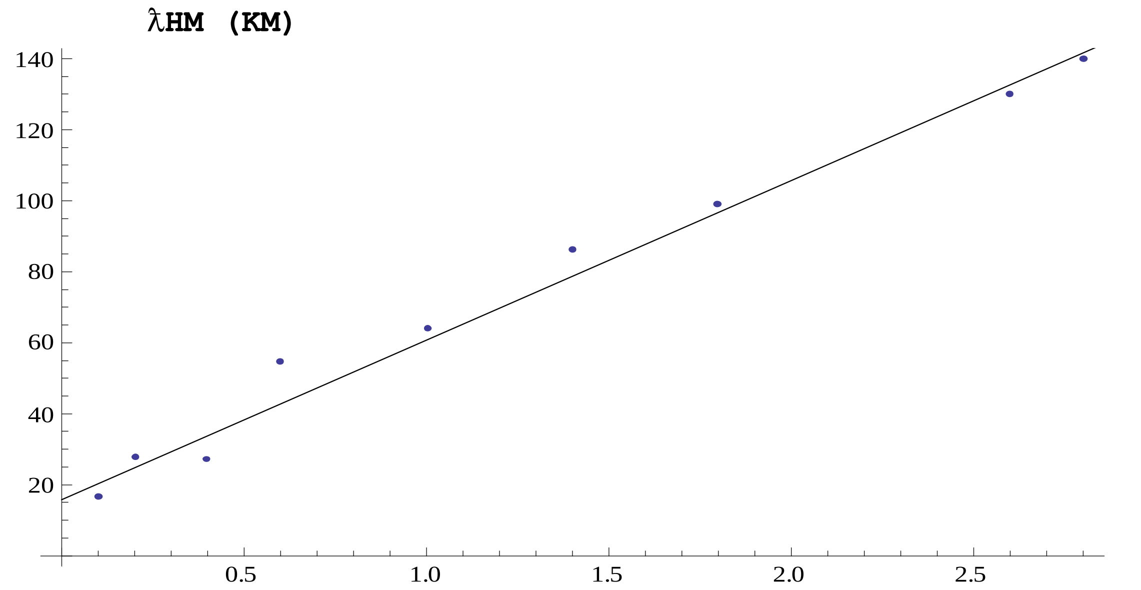
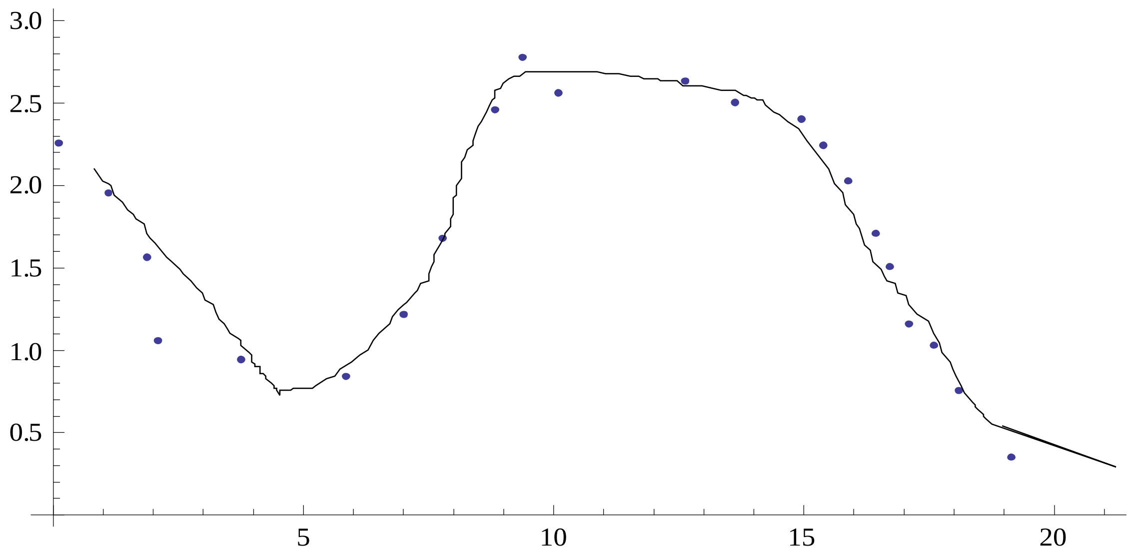


Fig 6

ListPlot[{{00.0,2.3},{1.0,2.0},{2.0,1.1},{3.0,0.4},{4.0,0.1},{5.0,1.3},{6.0,1.4},{7.0,1.6},{8.0,2.6},{9.0,2.9},{10.0,2.6},{11.0,1.6},{12.0,0.6},{13.0,0.4},{14.0,2.7},{15.0,3.4},{16.0,3.0},{17.0,1.2},{18.0,0.8},{19.0,0.4},{20.0,1.6},{21.0,2.4}}]

JUNE SOLSTICE CORRECTED FOR ƛh_m(km)

(MHz)

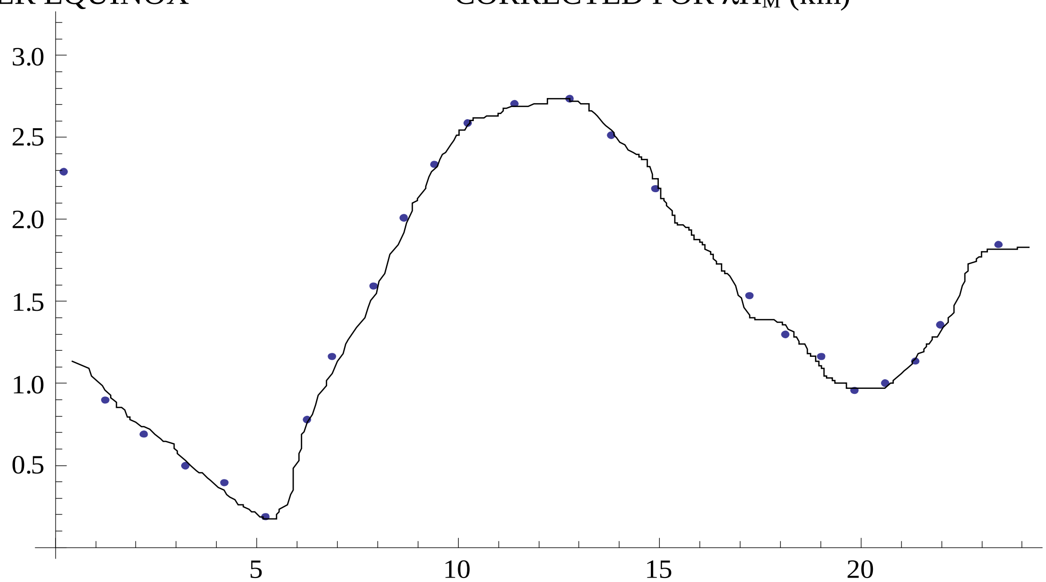


ƛ$f_O f_O$

Fig 8 Time in hrs

ListPlot[{{0.0,2.2},{1.0,0.8},{2.0,0.6},{3.0,0.4},{4.0,0.3},{5.0,0.1},{6.0,1.2},{7.0,1.6},{8.0,2.0},{9.0,3.0},{10.0,1.4},{11.0,1.2},{12.0,0.8},{13.0,2.0},{14.0,2.8},{15.0,3.2},{16.0,2.8},{17.0,1.4},{18.0,0.6},{19.0,0.2},{20.0,0.4},{21.0,0.1},{22.0,1.0},{23.0,1.8},{24.0,2.6}}]

SEPTEMBER EQUINOX CORRECTED FOR ƛH_M (km)



ƛ$f_O f_O$(MHz)

Fig 7 Time in hrs